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Acute Effects of Whole-Body Vibration on Muscle Strength in Subjects with Shoulder Instability

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SUMMARY

Background. Whole-body vibration (WBV) has proven to be an efficient tool in improving the physical qualities of the neuromuscular system, such as increasing muscle strength, performance, joint stability, electromyographic signal, proprioception, among others. Its use in the upper limbs and joint instabilities has shown good immediate results in a single session. The aim of this study was to analyze the acute effects of the use of mechanical vibration on the muscle strength of subjects with shoulder instability.

Methods. 10 athletes in the process of post-surgical rehabilitation of shoulder instability were volunteers in this study. Muscle strength was tested in the internal (IR) and external (ER) rotation movements in the neutral position using isokinetic dynamometry at two angular velocities – 60 and 180°/s in three moments: before, immediately after, and 10 minutes after the application of WBV. The WBV was applied only once, using a frequency of 30 Hz, with the patient assuming the arm flexion position on the platform during 5 series of 30 seconds of stimulation.

Results. The limb with shoulder instability benefited in both movements – ER and IR – and in both angular velocities. The limb without instability, on the other hand, had increased strength only in the RI movements at 60°/s and RE at 180°/s.

Conclusions. It is concluded that a single session of WBV applied directly to the upper limbs is capable of acutely improving muscle strength in both limbs in subjects with shoulder instability, with the affected limb being the most benefited.

KEY WORDS

WBV; shoulder instability; vibratory platform; isokinetic dynamometry; upper limb.

INTRODUCTION

Whole-body vibration (WBV) is a training and rehabilitation system that mainly uses the technology of vibrating platforms and that has been demonstrating several positive therapeutic and physiological effects, such as improvement of muscle strength, blood circulation, blood perfusion, muscle performance, bone density, neuromuscular response, increased electromyographic signal (EMG), increased neuromuscular system response, improved sports performance, muscle tone, muscle flexibility, proprioception, muscle tone, among others (1-10).

This system has been widely used and studied due to its easy application, being a non-invasive method, with immediate acute effects, with short sessions, being widely disseminated in sports and rehabilitation centers, apart from having literary support on its effects. Positive in the neuromuscular system.

In view of the benefits achieved with WBV, the effects of this technology on the upper limbs have been studied in different populations with different objectives and application protocols. So far, the results obtained with this technology applied to the upper limbs have been the improvement of muscle activation, motor function, muscle power, EMG signal, performance, blood concentrations of testosterone and growth hormone, muscle dynamics, muscle activation, muscle strength, dynamic joint stability, coordination and proprioception, muscle fatigue and joint mobility in athletes, were the most studied population in the literature (5, 6, 11-16).

The intervention protocols were varied, however, most publications coincide with good results when using 30 Hz of frequency, a single session (acute effects), 3 series of stimulation, using the isometric arm flexion position with the hands on the platform. A single session of WBV application has shown positive results on the neuromuscular system and has been used as a protocol in several studies (5, 13-20).

Within the WBV studies, there are also those who investigated the effects of this technology on joint instabilities. So far, only ankle and knee instabilities have been studied and these ones have achieved positive results on the neuromuscular system of patients with joint instability. WBV application protocols in joint instabilities were similar to those used in upper limb studies (21-31).

Shoulder instability is a common injury that usually affects young athletes. This injury is associated with a high rate of recurrences, which is why, in many cases, surgical treatment is chosen followed by physiotherapy to restore the normal functions of the affected limb. The literature agrees that the treatment of anterior shoulder instability should start with a rehabilitation program aimed at improving the strength of dynamic stabilizers, neuromuscular coordination and proprioception of the glenohumeral and scapulothoracic joints (32).

Patients with shoulder instability have a neuromuscular imbalance in both shoulders and exercises that aim to improve neuromuscular qualities should be part of the treatment of this population. Physiotherapeutic treatment aims to restore functional stability, seeking a rebalance of strength between the rotator cuff, scapular and deltoid muscles, thus restoring dynamic joint protection through neuromuscular balance (32-34).

Bearing in mind the needs of patients with shoulder instability and the positive effects that WBV has been achieving on muscle strength and joint instabilities, the aim of this study was to investigate the acute effects of WBV on the muscle strength of patients with shoulder instability.

MATERIALS AND METHODS

In this study, 10 athletes with shoulder instability aged between 18 and 46 years old participated, 9 men and 1 woman with body weight of 69 ± 12 Kg. Patients who had previously undergone surgery to correct instability, who were released for physiotherapeutic treatment and with a history of recurrence prior to surgery were included. Patients with contraindications for the use of WBV, such as retinal detachment, pregnancy, deep venous thrombosis, use of a pacemaker, spondylolysis, acute infections, pulmonary embolism or undergoing cancer treatment, were excluded. The sample was obtained from patients operated on for shoulder instability at the Unifesp Sports Medicine Outpatient Clinic (Federal University of São Paulo) over a period of 1 year and a half. All participants were volunteers and signed an informed consent form, following ethical standards established in the Declaration of Helsinki of 1946 and it was approved by the Ethics Committee of Federal University of Sao Paulo – registration number 47115421.3.0000.5505 (date of approval: July 15, 2021).

In the intervention with WBV, a KIKOS vibrating platform, model P2020ix, was used and consisted of a single stimulation session that had 5 series of 30 seconds of stimulation at 30Hz frequency with 30 seconds of rest between series. Patients were positioned with their hands on the platform in an isometric arm flexion position keeping their limbs rigid. Due to the isometric posture, blood pressure was measured during the process (**figure 1**).

Figure 1. Isometric push-up positioning on the platform.

Muscle strength analysis

Muscle strength was measured using isokinetic dynamometry – the gold standard for assessing this variable and is already used in many studies on shoulder instability (34-37). A Biodex III model isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY) was used. The variable considered for strength values was peak torque and positioning on the isokinetic dynamometer followed the literature recommendations for strength studies in patients with shoulder instability (32). Strength measurements were taken at 3 moments: before WBV, immediately after and 10 minutes after stimulation.

The positioning of the patient on the dynamometer was established according to a 2011 systematic review that dictates the best positioning of the patient in studies that use an isokinetic dynamometer to measure the strength of the shoulder rotators, where the most positive and reliable results are achieved, apart from being more comfortable and safer for the patient. This positioning consisted of having the patient sitting, maintaining a 45° shoulder abduction, with the forearm in a neutral position and with the trunk and pelvis fixed to avoid compensations (35) (**figure 2**).

Figure 2. Positioning on the isokinetic dynamometer.

The strength was measured in the RE and IR movements, with 3 repetitions for each one of them. The best of the repetitions was assumed for the statistical calculations. Strength was measured at two different angular velocities: 60 and 180°/s in concentric/concentric mode. Both upper limbs were tested – the affected one and the one without instability. Before the valid test, the patients were familiarized with the machine, performing three repetitions of the movements at 30°/s and the device was previously calibrated according to the manufacturer's instructions.

RESULTS

Peak torque was the value considered for the strength variable. Data were processed using the JASP program version 0.17.1.0. A descriptive analysis was performed to verify the normality of the data using the Shapiro-Wilk test and then the Wilcoxon test for simple paired samples. Statistically significant values were considered those smaller than $p < 0.05$.

In the external rotation movement at 60°/s there was a statistically significant increase in strength only in the unstable limb immediately after WBV and 10 minutes later.

Table I shows the results obtained for each patient for the external rotation movement at 60º/s.

In the internal rotation movement at 60°/s, there was also a significant increase in muscle strength, this time, in both limbs, with and without instability, immediately after WBV and 10 minutes later. **Table II** shows the results for each subject.

Table I. Muscle strength in the external rotation movement at 60°/s.

Upper limb without instability					Upper limb with instability				
Subject	**Before**	**After**	**10 minutes later**	**≠**	**Before**	**After**	**10 minutes later**	**≠**	**Predominance of the upper limb with instability**
1	348	352.4	353.5	5.5	229.8	234.5	233.8	4.7	Left-handed
2	418.9	434.4	434.1	15.5	346.6	349.9	350.2	3.6	Left-handed
3	346.8	354.6	350.9	7.8	261.4	275.2	276.1	14.7	Left-handed
4	51.8	73.6	72.4	21.8	47.8	54.9	54.1	7.1	Left-handed
5	347.6	346.3	348.5	0.9	204.6	229	221.1	24.4	Left-handed
6	229.9	230	229.7	0.1	346.7	348	347.7	1.3	Righty*
7	348.3	347.9	347.6	-0.4	227.7	228.7	229.5	1.8	Left-handed*
8	349.7	346.9	347.4	-2.3	347.6	347	346.9	-0.6	Left-handed*
9	347.6	347	347.6	0	229.5	227.6	229.5	0	Left-handed
10	347.9	346.9	346.1	-1	228.7	229.6	229.8	1.1	Righty*
Average	313.65	318	317.78	4.79	247.04	252.44	251.87	5.81	

Peak torque values in N-M. *Patients whose limb affected by instability was also the dominant one.

Table II. Muscle strength in the internal rotation movement at 60°/s.

	Upper limb without instability				Upper limb with instability				
Subject	**Before**	**After**	**10 minutes later**	**≠**	**Before**	**After**	**10 minutes later**	**≠**	**Predominance of the upper limb with instability**
1	157.9	161.2	167.7	9.8	110.2	121.6	123.2	13	Left-handed
2	159.3	162.4	163.4	4.1	89.9	101.6	102.8	12.9	Left-handed
3	157.9	158.2	158.8	0.9	69.8	78.8	79.4	9.6	Left-handed
4	33.2	39	39.4	6.2	33.4	53.4	52.9	20	Left-handed
5	222	229.7	218.4	7.7	109.9	115.2	114.8	5.3	Left-handed
6	157.6	157.8	159.2	1.6	112.6	109.8	113.2	0.6	Righty*
7	157.4	157	158.4	1	109.2	110.9	110.4	1.7	Left-handed*
8	158.1	158	158.2	0.1	110.4	110.4	110.8	0.4	Left-handed*
9	158	158.2	158	0.2	109.7	110.3	109.7	0.6	Left-handed
10	157	158.6	159.6	2.6	110.2	110.4	110.4	0.2	Righty*
Average	151.84	154.01	154.11	3.42	96.53	102.24	102.76	6.43	

Peak torque values in N-M. *Patients whose limb affected by instability was also the dominant one.

For the external rotation movement at 180°/s, there was a significant improvement in strength in both upper limbs – with and without instability, both immediately after WBV and 10 minutes later. **Table III** shows the results for each subject. For the internal rotation movement at 180°/s there was a significant increase in strength only in the limb with instability immediately after WBV and 10 minutes later. **Table IV** shows the results for the internal rotation movement at 180°/s.

In summary, the limb with instability benefited in both movements – ER and IR – and in both angular velocities 60 and 180°/s. The limb without instability, on the other hand, had increased strength only in the RI movements at 60°/s and RE at 180°/s.

Table III. Muscle strength in the external rotation movement at 180°/s.

	Upper limb without instability				Upper limb with instability				
Subject	**Before**	**After**	**10 minutes later**	**≠**	**Before**	**After**	**10 minutes later**	**≠**	**Predominance of the upper limb with instability**
1	342.7	349.1	349.5	6.8	243.6	251.2	249.8	7.6	Left-handed
2	344.6	351.2	348.9	6.6	346.6	349.9	351.2	4.6	Left-handed
3	345.5	349.9	351.1	5.6	288.2	299.6	302.8	14.6	Left-handed
4	64	73.6	72.4	9.6	46.8	54.9	54.1	8.1	Left-handed
5	346.9	346.9	348.5	1.6	241.1	249.4	247.1	8.3	Left-handed
6	344.6	345	347	2.4	245	243	229	-2	Righty*
7	344.7	343.7	345.2	0.5	245.6	246.1	242.4	0.5	Left-handed*
8	345.5	346.9	347	1.5	344.2	344	342	-0.2	Left-handed*
9	343.7	343.3	343.7	0	245.5	244.5	245.5	0	Left-handed
10	343.1	345.1	343.7	0.6	244.2	243.5	244.5	0.3	Righty*
Average	316.53	319.47	319.7	3.52	249.08	252.61	250.84	4.18	

Peak torque values in N-M. *Patients whose limb affected by instability was also the dominant one.

Table IV. Muscle strength in the internal rotation movement at 180°/s.

	Upper limb without instability				Upper limb with instability				
Subject	Before	After	10 minutes later	≠	Before	After	10 minutes later	≠	Predominance of the upper limb with instability
1	156.7	161.2	167.7	11	118.2	122.7	123.2	5	Left-handed
2	155.2	162.4	163.1	7.9	89.9	101.6	102	12.1	Left-handed
3	158.2	158.2	157.2	0	78.3	78.8	79.4	1.1	Left-handed
4	46.8	52.4	53.1	6.3	33.6	39	39.4	5.8	Left-handed
5	221.5	229.7	218.4	8.2	115	116.8	115.4	1.8	Left-handed
6	156.7	156	154.8	-0.7	116.1	114.9	118.2	2.1	Righty*
7	157.5	156.7	155.5	-0.8	115.8	114.4	115.5	-0.3	Left-handed*
8	156.1	155.4	157.4	1.3	111.5	112	110.4	0.5	Left-handed*
9	156.2	155.4	156.4	0.2	116.5	117.1	116.5	0.6	Left-handed
10	157	155.5	157.3	0.3	115.5	116.2	118.3	2.8	Righty*
Average	152.19	154.29	154.09	3.37	101.04	103.35	103.83	3.15	

Peak torque values in N-M. *Patients whose limb affected by instability was also the dominant one.

DISCUSSION

It is already known that WBV achieves positive effects on the neuromuscular system, such as strength, EMG signal, muscle activation, performance, induces increased blood concentrations of testosterone and growth hormone, improves muscle dynamics, muscle activation, dynamic joint stability, coordination and proprioception, muscle fatigue and joint mobility (4, 11, 16, 19, 20, 38-42). Due to these benefits, this technology has been tested in different audiences, such as athletes, in this case. The application of WBV on the upper limbs has been proving to be an effective technique to generate these neuromuscular improvements and a single application session has been proving to be sufficient to generate significant acute effects.

The studies published so far have used different protocols and publics, however, they coincide with some elements in their design. So far, 23 studies have applied WBV to the upper limbs with positive results in the neuromuscular system. Of these 23 studies, 19 studied the acute effects of a single application session, 12 of them used the frequency of 30 Hz, 12 used the arm flexion position on the platform and 9 studied the sports population - which is usually the most affected by injuries that culminate in joint instability (5, 6, 11-20; 38, 39; 43-50).

As in this study, the arm flexion position on the platform was the most used in the literature, achieving good results in strength, EMG signal and upper limb performance. This positioning allows the vibration to be applied directly to the MMSS. The study by Delkhoush *et al.* was the only one that did not achieve good results in what it proposed (ULL EMG signal), and, of all the studies, this was the only one that did not use vibration applied directly to the upper limbs – assuming the squatting position on the platform – which may explain the negative results (50). Other studies that applied vibration directly to the upper limbs had better results. In view of the findings, it seems that the vibration applied directly to the upper limbs is the one that produces the best results.

This study also agrees with the literature showing that a single session of WBV achieves acute positive effects on the neuromuscular system of the upper limbs and that 30 Hz of stimulation – the frequency preferred by previous studies – manages to generate positive effects.

Isokinetic dynamometry is the gold standard for assessing muscle strength, being the most indicated technology to be used in patients with shoulder instability. The positioning used is the safest, most efficient and with the most reliable results according to the systematic review on isokinetic studies in patients with shoulder instability published by Assunção *et al.* in 2019 (34). Having followed these indications may have been an important factor that justifies the positive results of this study in increasing muscle strength.

So far, 10 studies have been published that used WBV in joint instabilities, addressing only ankle and knee instability – all of them with positive results on the neuromuscular system of these dysfunctions (21-28, 31). This is the first study in which the WBV technology was applied in shoulder instability.

Shoulder instability caused by traumatic stress is a very common injury in young athletes and sportsmen. These patients are highly subject to dislocation recurrence due to the associated injury to the glenoid labrum and there are important losses of neuromuscular function (51).
The literature agrees that the treatment of anterior shoulder instability should start with a rehabilitation program aimed at improving the strength of dynamic stabilizers, neuromuscular coordination and proprioception of the glenohumeral and scapulothoracic joints (32).
Patients with shoulder instability have a neuromuscular imbalance in both shoulders (with and without instability) and exercises that aim to improve neuromuscular qualities should be part of the treatment of this population (32, 33).
Physiotherapeutic treatment aims to restore functional stability, seeking a rebalance of strength between the rotator cuff, scapular and deltoid muscles, thus restoring dynamic joint protection through neuromuscular balance.
Two studies by Eshoj *et al.* clearly state that neuromuscular exercises more efficiently improve shoulder function compared to standard exercises in patients with traumatic shoulder dislocation (51, 52).
Salles *et al.* recommend that strength exercises of the same intensity produce a greater increase in shoulder joint proprioception compared to exercises that vary it. It also says that neuromuscular exercises that activate the muscle spindle are the most suitable for improving shoulder control (53). The vibrating platform has the characteristic of maintaining a constant stimulus of the same intensity, apart from the already mentioned effects on the neuromuscular system of the upper limbs.
We consider that the positive results of this study in the increase of muscle strength in the IR and ER movements of the shoulder are due to: a positioning that allows direct stimulation of the upper limbs; the frequency of 30 Hz, which has shown positive effects in previous studies; the use of isokinetic dynamometry, which is the most appropriate tool to measure the muscle strength of individuals with shoulder instability and that the WBV promotes precisely those neuromuscular qualities that individuals with shoulder instability lack.
The increase in muscle strength promoted by WBV has already been theorized in several studies and this is based mainly on the increase in the intensity and amount of reflex muscle contractions generated by vibration, which is capable of increasing the EMG signal and local concentrations of testosterone and human growth hormone.
This study is in line with the literature showing that a single application of WBV on the upper limbs was able to generate strength improvement in both limbs in subjects with shoulder instability. The 30 Hz frequency seems to be the most adequate together with the arm flexion position on the platform. A single session seems to be enough to generate acute effects on the neuromuscular system of the upper limbs. This study also agrees with the literature showing that patients suffering from joint instability lack muscle strength in both limbs and benefit from the neuromuscular effects of WBV, suggesting that this technology can be a useful tool in the rehabilitation process of this dysfunction.
According to the results of this study, the technology of vibrating platforms can be a resource used in the rehabilitation of subjects with shoulder instability, not only for the improvement of the strength and function of the shoulder, but also for being a resource with fast application, simple, acute effects, being a painless and non-invasive technique.

CONCLUSIONS

A single session of WBV applied directly to the upper limbs is capable of acutely improving muscle strength in both limbs in subjects with shoulder instability, with the affected limb being the most benefited. Thus, this technology could be used in the rehabilitation of these patients, improving muscle strength and shoulder function.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

USLGdS: data collection, writing – original draft. BE: writing – review & editing, methodology (laboratory equipments).

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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